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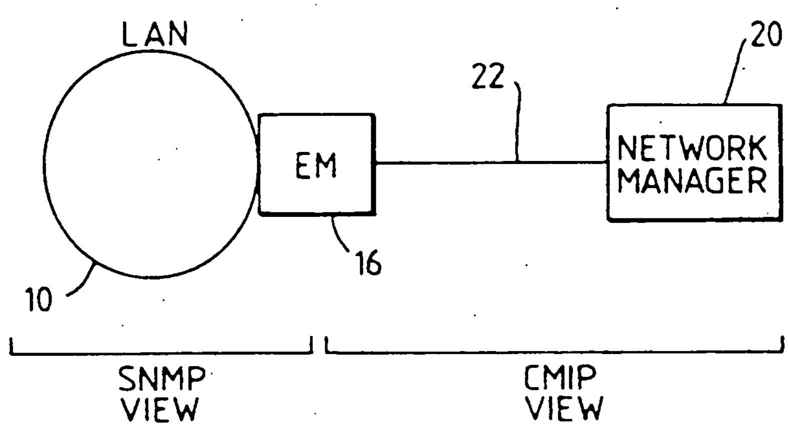

(57) Abstract

An internetwork system has several interlinked computer networks, each network having an associated element manager (16) which is arranged to communicate with a router via a first network management protocol. Each element manager (16) has means for converting from the first network management protocol to a second protocol and also has means for communicating via the network manager (20). The network manager (20) allows a user of the system to control a router by issuing a command at the network manager and/or to view information on the status, configuration and/or performance of the router.

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GENERIC MANAGED OBJECT MODEL FOR LAN DOMAIN

The present invention relates to a Generic Managed Object Model for a LAN Domain, and in particular a model which includes the capability of dealing with ports and routers.

Current systems incorporating managed object models are rather limited as to the amount of control provided to the user, and also the amount of information on the internetwork system which is provided. Currently agreed standards for managed object models are presently inadequate, and there are no agreed standards whatsoever for the interface via which a network manager, controlling an internetwork, may communicate with the individual element managers which form part of the internetwork.

According to the invention there is provided an internetwork system comprising a plurality of interlinked computer networks, each network having an associated manager arranged to communicate with elements on its respective network via a first network management protocol, and at least some managers including means for converting from the first network management protocol to a second protocol and further including means for communicating via the second protocol with a network manager, the network manager including control and information means arranged to allow a user of the system to control an element by issuing a command at the network manager and/or to view information on the status, configuration and/or performance of the element.

The network manager may include a database, arranged to store a model of the internetwork. The model may be stored as a managed object class model, according to the Common Management Information Protocol (CMIP). As an alternative (but not preferred) embodiment, it could be envisaged that the managers and the network manager might communicate via SNMP, with the conversion from SNMP to CMIP being carried out by the network manager. Also, it would be possible for the managers to communicate with their respective routers and other elements using some protocol other than SNMP. The elements may be routers, bridges, hubs, WAN managers, LAN managers or other elements.

The internetwork may include alarm means for raising an alarm against a particular element, and passing that information on to the network manager. Port alarm means may also be provided for raising an alarm against an individual port, or an individual line, or a particular router. The internetwork may also provide means for collecting performance information related to a particular router, and/or for ascertaining the configuration may

be passed on to the network manager, where it may be displayed graphically, in text form, or by means of auditory alarms. Means may also be provided for controlling a router and/or its ports via the network manager.

The invention may be carried into practice in a number of ways, and one specific embodiment will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic view of an internetwork system as a whole;

Figure 2 shows the interface between the network manager and the individual element manager LAN;

Figure 3 is an example of how information might be organised within the network manager;

Figure 4 shows, schematically, a generalised version of Figure 3;

Figure 5 shows a further schematic view of the internetwork system;

Figure 6 shows in schematic form a managed object class;

Figure 7 is an explanatory diagram;

Figure 8 shows a schematic view of part of the internetwork system;

Figure 9 shows a managed object model class structure used in the internetwork system.

Turning first to Figure 1, an exemplary internetwork system comprises first and second local area networks, 10, 12, linked by appropriate data cabling 14. Each LAN has its own separate proprietary element manager 16, 18. Each LAN may operate according to its own protocol: for example the LAN 10 might use the token ring system, and the LAN 12 might be an ethernet set up.

Sitting apart from the internetwork is a network manager 20, which receives information from the internetwork, and returns commands, via a link which is schematically illustrated

at 22. Information passing along this line actually goes either directly to the element managers 16, 18, or is routed, if appropriate, via the data cables 14 to the element manager. The network manager 20 may also receive information and issue instructions along a further line schematically illustrated at 24 from the "private domain" 26 of the user of the LAN 10. The "private domain" 26 might for example be the privately owned networks and network devices of a particular organisation. The data cables 14 might typically be publicly or privately owned cables provided by a telecommunication authority. The LAN 12 might be a public system, or perhaps another private system.

The purpose of the network manager 20 is to give a user of the entire internetwork system, sitting at C, the management information and control he needs to manager the internetwork. For example, the user A of the LAN 12 might be having difficulty in transferring a file from his own workstation to the workstation of B on the LAN 10. The person in charge of the internetwork manager, at C, would have an overview of the entire system and would be able to advise A and B what the problem was and how it might be solved. In a more complicated system (not shown) comprising more than two interlinked LANs, the network manager 20 is able to control the appropriate routers to force data to travel along a particular path. If the normal data path is unavailable for some reason, because of a fault, the network manager 20 would be able to issue a command to one or more of the routers to transfer the information via a different route.

It is of course essential that the network manager 20 is able to communicate with each of the individual proprietary element managers. These element managers may be manufactured by different companies and each controls its own individual LAN using SNMP. To ensure well defined communication with the network manager, the present embodiment envisages that each of the proprietary element managers will support CMIP for communicating with the network manager and SNMP for communicating with is own elements. The network manager communicates with the individual element managers using CMIP and a managed object model which is chosen to provide the necessary functionality for the user of the network manager. In the preferred embodiment, the element manager translates the SNMP information into CMIP. This is schematically illustrated in Figure 2. Both SNMP (Simple Network Management Protocol) and CMIP (Common Management Information Protocol) are protocols which are well known to the skilled man in this field.

The network manager 20 maintains a model of the overall internetwork, essentially by storing information about the physical make up of the internetwork, its status and performance, in a suitably designed form according to the CMIP standard. A suitable

network manager for this purpose is the manager known as "Concert IMS" available from British Telecommunications PLC. whose registered office is 81. Newgate Street, London EC1A 7AJ.

The model of the internetwork which is stored within the network manager is based upon managed objects, each of which is effectively a database entry representing a management view of a particulary resource. The model provides for individual instances of each particular resource, for example each individual router within the internetwork, and it also provides for classes, for example the class of all routers. In those terms, the model may therefore by thought of as a series of interlinked managed object classes.

To take a particular example. as shown in Figure 3, one of the managed object classes is called "network" and individual instances within this class might comprise the overall internetwork, an individual LAN network. an individual LAN segment, a hub and so on. The class "network" therefore effectively provides for partitioning the database such that the make-up of the particular internetwork or LAN can be represented as a database template which can be filled in different ways, according to what the particular instance represents. The database entries are linked together hierarchically, as shown in Figure 3, to indicate for example that the LAN network, the LAN segment and the hub are all individual parts of the overall internetwork.

A further managed object class is called "equipment", which has particular instances including a bridge, a PC and a workstation, all of which are component parts of the LAN network in this example. Another part of the LAN network is a router, which has its own special class called "router". Each router may have several ports (representing individual wires), ports having their own special class called "port".

Whereas Figure 3 shows a typical example of part of the model, Figure 4 shows the overall model in a more generalised way. Starting at the top, it will be seen that the managed object class "network" may have links to any number of subsidiary but identical "network" managed object classes. Any network class may itself have links to any number of "equipment" managed object classes, and to any number of "router" managed object classes. The "router" class has links to single class entitled "route table entry", and to any number of "port" classes, each representing an individual wire on one of the routers. The "router class is similarly connected to a "location" class, defining where the individual routers are physically located, and also to a number of "vendor" classes, which define the vendor of each of the routers. Each vendor may have a number of contacts, for example an individual

person to be contacted in the event of a problem, and those contacts may themselves be associated with a particular location such as an address or a telephone number.

The rest of the diagram follows in a similar way, and will no doubt be self explanatory.

In the present embodiment, the managed object classes entitled "router", "route table entry" and "port" are new.

The "router" managed object class includes the attributes which are normally associated with the "equipment" class, with a number of additions. These include

goodResponseIn	goodResponsesInThreshold
goodResponseOut	goodResponsesOutThreshold
inAddressErrors	inAddressErrorsThreshold
unroutablePackets	unroutablePackets

These allow a user of the internetwork manager to obtain information on the routers, and to set and monitor threshold, traffic and performance alarms. In particular, information or alarms may be obtained in respect of address errors in datagrams forwarded, unroutable packets, unknown protocol packets, error packets in and out, good responses in and out, bytes in and out, and discard packets in and out.

The performance parameters associated with the new "port" managed object class are:

bytesin	bytesInThreshold
bytesout	bytesOutThreshold
discardPacketsIn	discardPacketsInThreshold
discardPacketsOut	discardPacketsOutThreshold
errorPacketsIn	errorPacketsInThreshold
errorPacketsOut	errorPacketsOutThreshold
unknownProtocolPackets	UnknownProtocolPacketsThreshold

Each performance attribute may have three values:

(a) A polling interval that is settable.

(b) A differential value which indicates the change in value of the performance parameter over the given polling interval.

(c) A total value that gives the value of the corresponding SNMP counter for the respective performance parameter.

An attribute change notification is sent on the completion of each polling interval. To allow the reporting of alarms against performance parameters, there is a threshold which is associated with each "performance" attribute. The relevant alarms are transmission alarms with problem type transmissionError, and these are sent when the threshold criteria set for a particular performance for a LAN device has been met. The criteria for each threshold are a set of maximum allowable counts in a given time frame, and a severity level associated with that threshold.

The "port" managed object class also includes the following port attributes which related to configuration management:

portControl	portSpeed
portForwarding	portPhysicalAddress
portIndex	portType
portIpAddress	adminState
portIpMask	opState
	typeText

A description of these attributes follows:

portControl	this allows the port to be switched on or off.
portForwarding	this indicates whether the system from/to which traffic is being routed is an end or intermediate system.
portIndex	This identifies the port (logical number).
portIpAddress	This gives the logical address of the port.
portIpMask	This provides the information to interpret the logical address.

portPhysicalAddress	This gives the physical address of the port.
portSpeed	This provides an estimation of the bandwidth of the link connected to the port.
portType	This gives a description of the type of interface at the port.

The "route table entry" managed object class includes the following attributes:

routeAge	routeMask
routeControl	routeMetric
routeDestination	routeNextHop
routeInterfaceIndex	routeProtocol

A brief description of these attributes is given below:

routeAge	This indicates the last time that a packet that traversed the network was received.
routeControl	This allows the ports to be switched on and off.
routeDestination	This indicates the masked IP address. It gives the network part of the address only.
routeInterfaceIndex	This indicates which port on the router is being used. It identifies the port.
routeMask	This allows the IP address to be interpreted to give the network address indicated by routeDest attribute.
routeMetric	This gives an idea as to the costing of the route. There are give route metrics in SNMP but only one attribute with two values will be used to represent it for management purposes. The first

	value will indicate the route metric and the second will be the value of that route metric.
routeNextHop	This indicates the next IP address on the route.
routeProtocol	This indicates which protocol is being used and gives understanding to the route metric.

As was previously mentioned in connection with Figure 2, the preferred embodiment provides for a translation by the element manager from SNMP to CMIP.

The internetwork system is shown in greater detail in figure 5. It can be seen that the network manager 20 comprises a computer terminal of known type loaded with a Concert (TM) Network Management System computer program. The element manager 16 also comprises a computer terminal of known type loaded with and operating a LAN management program. This enables the element manager 16 to communicate with the equipment on its local area networks 10 comprising subnetworks A, B and C. The equipment may include workstations 53, servers, hubs and routers 54.

Communication between equipment in subnetwork A and the element manager 16 is by means of SNMP as represented by arrow 51 whilst communication between the element manager 16 and the network manager 20 is by means of CMIP as represented by arrow 52.

The network manager 20 has a model of the complete internetwork which identifies the local area networks, the internetworking elements such as routers and bridges, and the devices attached to the LANs. The network manager 20 also contains a model of the elements of the wide area network subnetworks. The model is formed as a managed object model and an example of the model is shown in figure 6.

It can be seen that the internetwork is given a networkID of "btInternet" 61 and the managed object class containment structure is used to provide an hierarchial network topology. "btInternet" is the top level network managed object instance. This contains all the other networks that is to say those having networkID "192.112.4.0" 62 and "192.112.45.0" 63 and router 64.

"192.112.4.0" and "192.112.45.0" each contain subnetworks. There are logical partitions of the internetwork based on the network addressing scheme.

The LAN element manager 16 also provides a model of its associated network which can be thought of as in interface model which is offered to the network manager 20. This model is shown in figure 7 by an entity relationship diagram.

The model utilises the following managed object classes as defined in the Network Management Forum Managed Object Library issue 1.1 (which is a collection of managed object instances well known to those skilled in the art):

addValueEventRecord
agentCME
alarmRecord
attributeChangeEventRecord
computerSystem
deenrolObjectEventRecord
enrolObjectEventRecord
equipment
eventLog
eventReportingSieve
location
network
removeValueEventRecord
root

All mandatory features of each Network Management Forum managed object class are required. In addition, optional attributes are required as will be later described.

The alarmRecord managed object class will hold as attributes all the populated fields of the relevant M-EVENT-REPORT.

The computerSystem managed object class will have the following optional attributes as mandatory attributes.

PeripheralNames;
UpTime; and
UserLabels

The userLabels attribute is used to list the applications that the device supports.

Instances of the equipment managed object class represents the physical components of the network such as bridges, routers, hubs and terminal servers. For this class the following attributes are mandatory:

equipmentType;
functionNames;
networkNames;
productLabel;
serialNumber;
typeText; and
userLabels.

For the eventLog managed object class, the following optimal attributes are made mandatory:

capacityAlarmThreshold;
logFullAction; and
timeOfLastEntry.

Instances of the location managed object class represent the location of physical aspects of the network and are used for inventory and configuration management purposes. The following optional forum attributes are made mandatory:

typeText; and
userLabels.

Instances of the network managed object class are used to represent the internetwork, subnetwork and LAN segments and the optional attribute userLabels is made mandatory.

In order to meet the requirement of LAN management, the model includes subclasses from the Network Management Forum managed object classes equipment and top.

The subclasses are shown in figure 9 which depicts an inheritance structure for the LAN Model managed object classes. Thus it will be seen the managed object class top 91 has subclasses network 92, equipment 93, portInfo 94, routeTable 95, summaryInfo 96, location

97 computerSystem 98 the forum managed object class equipment 93 has a subclass lanPort 99 whilst top 91 has the additional subclasses portInfor 94 and routeTable 95.

In order to cope with protocol specific information, for example Internet Protocol (IP) further subclasses are provided. These are ipPartInfo managed object class 100, ipRouteTable managed object class 101 and ipSummaryInfo managed object class 102.

The managed object classes have the following behaviour and package specifications.

```
lanPort        MANAGED OBJECT CLASS
  DERIVED FROM "NM Forum Library Vol 1 Supplement":equipment;
  CHARACTERIZED BY lanPortPkg,
       "NM Forum Library Vol 1 Supplement": functionNamesPkg,
       "NM Forum Library Vol 1 Supplement": equipmentTypePkg,
       "NM Forum Library Vol 1 Supplement": networkNamesPkg,
       "NM Forum Library Vol 1 Supplement": typeTextPkg,
       "NM Forum Library Vol 1 Supplement": userLabelsPkg;
REGISTERED AS {?} ;

lanPortPkg    PACKAGE
       BEHAVIOUR lanPortPkgBehaviour;
       ATTRIBUTES
          lanPortIndex             GET,
          lanPortType              GET-REPLACE,
          lanPortSpeed             GET-REPLACE,
          lanPortPhysicalAddress   GET-REPLACE,
          lanPortLastChange        GET,
          lanPortSpecific          GET,
          lanPortLink              GET-REPLACE ADD-REMOVE;

       NOTIFICATIONS
          "NM Forum Library Vol 1 Supplement": transmissionAlarm;
;
lanPortPkgBehaviour BEHAVIOUR

DEFINED AS    ! This managed object class is used to represent the
physical aspects of an equipment port.  For example the port could
be on a router, a bridge, a workstation, or a computerSystem
object instance.
Port Link loss will be represented by a transmissionAlarm of
problem type linkDown. !;
```

portInfo

```
portInfo  MANAGED OBJECT CLASS
  DERIVED FROM "NM Forum Library Vol 1 Supplement":top;
  CHARACTERIZED BY portInfoPkg;
REGISTERED AS {?} ;

portInfoPkg   PACKAGE
   BEHAVIOUR portInfoPkgBehaviour;
   ATTRIBUTES
   portInfoID    GET,
   inOctets
        PERMITTED VALUES LanDomainModule.LPerCounterRange
        GET,
   outOctets
        PERMITTED VALUES LanDomainModule.LPerCounterRange
        GET,
   inDiscardPackets
        PERMITTED VALUES LanDomainModule.LPerCounterRange
        GET,
```

```
OutDiscardPackets
      PERMITTED VALUES LanDomainModule.LPerCounterRange
      GET,
inErrorPackets
      PERMITTED VALUES LanDomainModule.LPerCounterRange
      GET,
outErrorPackets
      PERMITTED VALUES LanDomainModule.LPerCounterRange
      GET,
inUnknownProtos
      PERMITTED VALUES LanDomainModule.LPerCounterRange
      GET;
;
port InfoPkgBehaviour  BEHAVIOUR

DEFINED AS      !This managed object class is used to hold the non protocol
specific statistics associated with a lanPort managed object instance. !;
```

ipPortInfo

```
ipPortInfo   MANAGED OBJECT CLASS
      DERIVED FROM portInfo;
      CHARACTERIZED BY ipPortInfoPkg;
REGISTERED AS {?} ;

ipPortInfoPkg PACKAGE
      BEHAVIOUR ipPortInfoPkgBehaviour;
      ATTRIBUTES
            lanPortIndex          GET,
            lanPortIpAddress      GET-REPLACE,
            lanPortIpMask         GET-REPLACE;
;
ipPortInfoPkgBehaviour  BEHAVIOUR
```

DEFINED AS !This managed object class is used to hold the IP protocol specific information associated with a lanPort managed object instance. The lanPortIndex attribute has the same value as the lanPortIndex attribute of the related LanPort managed object instance !;

routeTable

routeTable MANAGED OBJECT CLASS
DERIVED FROM "NM Forum Library Vol 1 Supplement": top;
CHARACTERIZED BY routeTablePkg;
REGISTERED AS {?} ;

routeTablePkg PACKAGE
BEHAVIOUR routeTablePkgBehaviour;
ATTRIBUTES
routeTableID GET;
;
routeTablePkgBehaviour BEHAVIOUR

ATTRIBUTES
summaryInfoID GET;

;
summaryInfoPkgBehaviour BEHAVIOUR

DEFINED AS ! The summaryInfo managed object class is used to represent the non-protocol specific statistical and general information associated with managed object instances representing equipment in the LAN domain.!;

ipSummaryInfo

ipSummaryInfoMANAGED OBJECT CLASS
DERIVED FROM summaryInfo;

```
        CHARACTERIZED BY ipSummaryInfoPkg;
REGISTERED AS {?} ;

ipSummaryInfoPkg PACKAGE
        BEHAVIOUR ipSummaryInfoPkgBehaviour;
        ATTRIBUTES
        ipInDelivers
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipInAddrErrors
                PERMITTED VALUES  LanDomainModule.LPerCounterRange
                GET,
        ipOutNoRoutes
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipForwarding
                GET-REPLACE,
        ipInReceives
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipInHdrErrors
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipForwDatagrams
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipInUnknownProtos
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
        ipInDiscards
                PERMITTED VALUES LanDomianModule.LPerCounterRange
                GET,
        ipOutRequests
                PERMITTED VALUES LanDomainModule.LPerCounterRange
                GET,
```

```
ipOutDiscards
      PERMITTED VALUES LanDomainModule.LPerCounterRange
      GET;
;
ipSummaryInfoPkgBehaviour  BEHAVIOUR
```

DEFINED AS ! The ipSummaryInfo managed object class is used to represent the IP specific statistical and general information associated with managed object instances representing routing equipment in the LAN domain. !;

Attribute definitions for the new objects

inDiscardPackets

inDiscardPackets ATTRIBUTE
    DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR inDiscardPacketsBehaviour;
REGISTERED AS {?} ;

inDiscardPacketsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of inbound packets which were chosen to be discarded even though no errors had been detected to prevent their being deliverable to a higher-layer protocol. !;

inErrorPackets

inErrorPackets ATTRIBUTE
    DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR inErrorPacketsBehaviour;
REGISTERED AS {?} ;

inErrorPacketsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of inbound packets that contained errors preventing them from being deliverable to a higher-layer protocol. ! ;

inOctets

inOctets ATTRIBUTE
    DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR inOctetsBehaviour;

REGISTERED AS {?} ;

inOctetsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the total number of octets received at the lanPort managed object instance, including framing characters. !;

inUnknownProtos

inUnknownProtos ATTRIBUTE
    DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR inUnknownProtosBehaviour;
REGISTERED AS {?} ;

inUnknownProtosBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of packets received via a lanPort managed object instance which were discarded because of an unknown or unsupported protocol. ! ;

ipForwarding

ipForwarding ATTRIBUTE
    WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwarding;
    MATCHES FOR EQUALITY;
    BEHAVIOUR ipForwardingBehaviour;
REGISTERED AS {?} ;

ipForwardingBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies whether the system from/to which traffic is being routed is an end or intermediate system. !;

ipForwardAge

```
ipForwardAge ATTRIBUTE
      WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwardAge;
      MATCHES FOR EQUALITY;
      BEHAVIOUR ipForwardAgeBehaviour;
REGISTERD AS {?} ;

ipForwardAgeBehaviour BEHAVIOUR

DEFINED AS
! This is a count, for each route, of the number of seconds elapsed since the last time the route was validated. ! ;
```

ipForwardDest

```
ipForwardDest ATTRIBUTE
      WITH ATTRIBUTE SYNTAX LanDomainModule.AddressSequence;
      MATCHES FOR EQUALITY;
      BEHAVIOUR ipForwardDestBehaviour;
REGISTERED AS {?} ;

ipForwardDestBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies, for each route, the destination IP address. ! ;
```

ipForwardIfIndex

```
ipForwardIfIndex ATTRIBUTE
      WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwardIfIndex;
      MATCHES FOR EQUALITY ;
      BEHAVIOUR ipForwardIfIndexBehaviour;
REGISTERED AS {?} ;
```

ipForwardIfIndexBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies, for each route, the lanPort managed object instance through which the next hop of the route should be reached.!;

ipForwardInfo

ipForwardInfo ATTRIBUTE
    WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwardInfo;
    MATCHES FOR EQUALITY;
    BEHAVIOUR ipForwardInfoBehaviour;
REGISTERED AS {?} ;

ipForwardInfoBehaviour BEHAVIOUR

DEFINED AS
! This attribute holds specific information related to the particular routing protocol which is responsible for each route. If the information is not present for a route, the entry in this attribute for that route will take a value of OBJECT IDENTIFIER {oo} .!;

ipForwardMask

ipForwardMask ATTRIBUTE
    WITH ATTRIBUTE SYNTAX LanDomainModule.AddressSequence;
    MATCHES FOR EQUALITY;
    BEHAVIOUR ipForwardMaskBehaviour;
REGISTERED AS {?} ;

ipForwardMaskBehaviour BEHAVIOUR

DEFINED AS
! This attribute indicates, for each route, the mask to be logically ANDed with the destination address before being compared to the value in the ipForwardDest attribute. !;

ipForwardMetric1

ipForwardMetric1 ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.ForwardMetric;
MATCHES FOR EQUALITY, ORDERING;
BEHAVIOUR ipForwardMetric1Behaviour;
REGISTERED AS {?} ;

ipForwardMetric1Behaviour BEHAVIOUR

DEFINED AS
! This attribute indicates the primary routing metric for each route. The semantics of this metric are determined by the value of the ipForwardProto attribute. !;

ipForwardMetric2

ipForwardMetric2 ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.ForwardMetric;
MATCHES FOR EQUALITY, ORDERING;
BEHAVIOUR ipForwardMetric2Behaviour;
REGISTERED AS {?} ;

ipForwardMetric2Behaviour BEHAVIOUR

DEFINED AS
! This attribute indicates the alternative routing metric for each route. The semantics of this metric are determined by the value of the ipForwardProto attribute.!;

ipForwardMetric3

ipForwardMetric3 ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.ForwardMetric;
MATCHES FOR EQUALITY, ORDERING;

BEHAVIOUR ipForwardMetric3Behaviour;
REGISTERED AS {?};

ipForwardMetric3Behaviour BEHAVIOUR

DEFINED AS
! This attribute indicates the alternative routing metric for each route. The semantics of this metric are determined by the value of the ipForwardProto attribute. !;

ipForwardMetric4

```
ipForwardMetric4 ATTRIBUTE
      WITH ATTRIBUTE SYNTAX LanDomainModule.ForwardMetric;
      MATCHES FOR EQUALITY, ORDERING;
      BEHAVIOUR ipForwardMetric4Behaviour;
REGISTERED AS {?} ;
```

ipForwardMetric4Behaviour BEHAVIOUR

DEFINED AS
! This attribute indicates the alternative routing metric for each route. The semantics of this metric are determined by the value of the ipForwardProto attribute. !;

ipForwardMetric5

```
ipForwardMetric5 ATTRIBUTE
      WITH ATTRIBUTE SYNTAX LanDomainModule.ForwardMetric;
      MATCHES FOR EQUALITY, ORDERING;
      BEHAVIOUR ipForwardMetric5Behaviour;
REGISTERED AS {?};
```

ipForwardMetric5Behaviour BEHAVIOUR

DEFINED AS
! This attribute indicates the alternate routing metric for each route. The semantics of this metric are determined by the value of the ipForwardProto attribute. !;

1001	18
1010	20
1011	22
1100	24
1101	26
1110	28
1111	30

Protocols defining policy otherwise must either define a set of values which are valid for this attribute or must implement and integer–instanced policy table for which this attribute's value acts as an index. !;

ipForwardProto

ipForwardProto ATTRIBUTE
    WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwardProto;
    MATCHES FOR EQUALITY;
    BEHAVIOUR ipForwardProtoBehaviour;
REGISTERED AS {?} ;

ipForwardProtoBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies, for each route, which protocol is being used and gives meaning to the route metric. !;

ipForwardType

ipForwardType ATTRIBUTE
    WITH ATTRIBUTE SYNTAX LanDomainModule.IpForwardType;
    MATCHES FOR EQUALITY;
    BEHAVIOUR inForwardTypeBehaviour;
REGISTERED AS {?} ;

DEFINED AS

! This attribute identifies, for each route, which protocol is being used and gives meaning to the route metric. !;

ipForwardTypeBehaviour BEHAVIOUR

DEFINED AS

! This attribute identifies for each route its type. !;

ipForwDatagrams

ipForwDatagrams ATTRIBUTE
    DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR ipForwDatagramsBehaviour;
REGISTERED AS {?} ;

ipForwDatagramsBehaviour BEHAVIOUR

DEFINED AS

! This attribute is a count of the number of input datagrams for which the containing managed object instance was not their final IP destination as a result of which an attempt was made to find a route to forward them to that final destination. !;

ipInAddrErrors

ipInAddrErrors ATTRIBUTE
    DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
    BEHAVIOUR ipInAddrErrorsBehaviour;
REGISTERED AS {?} ;

ipInAddrErrorsBehaviour BEHAVIOUR

DEFINED AS

! This attribute value is a count of the number of input datagrams discarded because the IP address in their IP header's destination field was not a valid address to be received. !;

ipInDelivers

ipInDelivers ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;

BEHAVIOUR ipInDeliversBehaviour;
REGISTERED AS {?} ;

ipInDeliversBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the total number of input datagrams successfully delivered to IP user-protocols. !;

ipInDiscards

ipInDiscards ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
BEHAVIOUR ipInDiscardsBehaviour;
REGISTERED AS {?} ;

ipInDiscardsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of input IP datagrams for which no problems were encountered to prevent their continued processing, but which were discarded. ! ;

ipInHdrErrors

ipInHdrErrors ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;

BEHAVIOUR ipInHdrErrorsBehaviour;
REGISTERED AS {?} ;

ipInHdrErrorsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of input datagrams discarded due to error in their IP headers, including bad checksums, version number mismatch, other format errors, etc. !;

ipInReceives

ipInReceives ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR ipInReceivesBehaviour;
REGISTERED AS {?} ;

ipInReceivesBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the total number of input datagrams received including those received in error. !;

ipInUnknownProtocols

ipInUnknownProtos ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR ipInUnknownProtosBehaviour;
REGISTERED AS {?} ;

ipInUnknownProtosBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of locally-addressed datagrams received successfully but discarded because of an unknown or unsupported protocol. !;

ipOutDiscards

ipOutDiscards ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992": counter;
BEHAVIOUR ipOutDiscardsBehaviour;
REGISTERED AS {?} ;

ipOutDiscardsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of output IP datagrams for which no problem was encountered to prevent their transmission to their destination, but which were discarded. !;

ipOutNoRoutes

ipOutNoRoutes ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR ipOutNoRoutesBehaviour;
REGISTERED AS {?} ;

ipOutNoRoutesBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of IP datagrams discarded because no route could be found to transmit them to their destination. !;

ipOutRequests

ipOutRequests ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR ipOutRequestsBehaviour;

REGISTERED AS {?} ;

ipOutRequestsBehaviour BEHAVIOUR

DEFINED AS

! This attribute value is a count of the total number of IP datagrams which local IP user-protocols supplied to IP in requests for transmission. !;

lanPortIndex

```
lanPortIndex ATTRIBUTE
        WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortIndex;
        MATCHES FOR EQUALITY;
        BEHAVIOUR lanPortIndexBehaviour;
REGISTERED AS {?} ;
```

lanPortIndexBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies the logical number allocated to the lanPort instance. !;

lanPortIpAddress

```
lanPortIpAddress ATTRIBUTE
        WITH ATTRIBUTE SYNTAX LanDomainModule.Address;
        MATCHES FOR EQUALITY;
        BEHAVIOUR lanPortIpAddressBehaviour;
REGISTERED AS {?} ;
```

lanPortIpAddressBehaviour BEHAVIOUR

DEFINED AS
! This attribute gives the logical IP address of the lanPort managed object instance. !;

lanPortIpMask

```
lanPortIpMask ATTRIBUTE
        WITH ATTRIBUTE SYNTAX  LanDomainModule.Address;
        MATCHES FOR EQUALITY;
```

BEHAVIOUR lanPortIpMaskBehaviour;
REGISTERED AS {?} ;

lanPortIpMaskBehaviour BEHAVIOUR

DEFINED AS
! This attribute provides the information to interpret the logical address. !;

lanPortLastChange

lanPortLastChange ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortLastChange;
MATCHES FOR EQUALITY, ORDERING;
BEHAVIOUR lanPortLastChangeBehaviour;
REGISTERED AS {?} ;

lanPortLastChangeBehaviour BEHAVIOUR

DEFINED AS

! This attribute identifies the sysUpTime at the time the lanPort managed object instance entered its current operational state. !;

lanPortLink

lanPortLink ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortLink;
MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
BEHAVIOUR lanPortLinkBehaviour;

REGISTERED AS {?} ;

lanPortLinkBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies a combination of the following:

an indication of the number of connections that the managed object instance holding this attribute is connected to;
the managed object (classes and) instances, (typically instances of accessPoint or terminationPoint on a WAN, or an instance of lanPort of another LAN device) that the managed object instance holding this attribute is connected to;
whether the connection is a bus connection;
that there is no connection. !;

lanPortPhysicalAddress

lanPortPhysicalAddress ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.Address;
MATCHES FOR EQUALTIY;
BEHAVIOUR lanPortPhysicalAddressBehaviour;
REGISTERED AS {?} ;

lanPortPhysicalAddressBehaviour BEHAVIOUR

DEFINED AS
! This attribute gives the physical address of the lanPort. !;

lanPortSpecific

lanPortSpecific ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortSpecific;
MATCHES FOR EQUALITY;
BEHAVIOUR lanPortSpecificBehaviour;
REGISTERED AS {?} ;

lanPortSpecificBehaviour BEHAVIOUR

DEFINED AS
! This attribute identifies a reference to definitions specific to the particular media being used to realise the lanPort.!;

lanPortSpeed

lanPortSpeed ATTRIBUTE

WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortSpeed;

MATCHES FOR EQUALITY, ORDERING;

BEHAVIOUR lanPortSpeedBehaviour;

REGISTERED AS {?} ;

lanPortSpeedBehaviour BEHAVIOUR

DEFINED AS

! This provides an estimation of the current bandwidth of the interface connected to the lanPort. For interfaces that do not vary in bandwidth or for those where no accurate estimation can be made this attribute should contain the nominal bandwidth. !;

lanPortType

lanPortType ATTRIBUTE

WITH ATTRIBUTE SYNTAX LanDomainModule.LanPortType;

MATCHES FOR EQUALITY;

BEHAVIOUR lanPortTypeBehaviour;

REGISTERED AS {?} ;

lanPortTypeBehaviour BEHAVIOUR

DEFINED AS

! This gives a description of the type of interface at the port. !;

outDiscardPackets

outDiscardPackets ATTRIBUTE

DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;

BEHAVIOUR outDiscardPacketsBehaviour;

REGISTERED AS {?} ;

outDiscardPacketsBehaviour BEHAVIOUR

DEFINED AS

! This attribute value is a count of the number of outbound packets which were chosen to be discarded event though no errors had been detected to prevent their being transmitted. !;

outErrorPackets

outErrorPackets ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR outErrorPacketsBehaviour;
REGISTERED AS {?} ;

outErrorPacketsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the number of outbound packets that could not be transmitted because of errors. !;
outOctets

outOctets ATTRIBUTE
DERIVED FROM "Rec. X. 721 | ISO/IEC 10165-2 : 1992" : counter;
BEHAVIOUR outOctetsBehaviour;
REGISTERED AS {?} ;

outOctetsBehaviour BEHAVIOUR

DEFINED AS
! This attribute value is a count of the total number of octets transmitted out of the lanport managed object instance, including framing errors. !;

portInfoID

portInfoID ATTRIBUTE

WITH ATTRIBUTE SYNTAX LanDomainModule.PortInfoID;

MATCHES FOR EQUALITY;
BEHAVIOUR portInfoIDBehaviour;

REGISTERED AS {?} ;

portInfoIDBehaviour BEHAVIOUR

DEFINED AS
! This portInfoID is an attribute type whose value can be used as a relative distinguished name when naming an instance of the portInfo class and its subclasses. !;

routeTableID

routeTableID ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.RouteTableID;
MATCHES FOR EQUALITY;
BEHAVIOUR routeTableIDBehaviour;
REGISTERED AS {?} ;

routeTableIDBehaviour BEHAVIOUR

DEFINED AS
! This routeTableID is an attribute type whose value can be used as a relative distinguished name when naming an instance of the routeTable class and its subclasses. !;

summaryInfoID

summaryInfoID ATTRIBUTE
WITH ATTRIBUTE SYNTAX LanDomainModule.SummaryInfoID;
MATCHES FOR EQUALITY;
BEHAVIOUR summaryInfoIDBehaviour;
REGISTERED AS {?} ;

summaryInfoIDBehaviour BEHAVIOUR

DEFINED AS

! This summaryInfoID is an attribute type whose value can be used as a relative distinguished name when naming an instance of the summaryInfo class and its subclasses. !;

Syntax of New Attributes

```
LanDomainModule {?}

DEFINITIONS IMPLICIT TAGS ::=
BEGIN
— IMPORTS
      CircuitBandwidth, Interger16, Name
      FROM FORUM-TYPES-GDMO-1
            {forum modules (0) types-GDMO-1 (8)},
      Count, ObjectInstance
      FROM Attribute-ASN1Module
            {joint-iso-ccitt ms(9) smi (3) part2(2) asn1Module(2)},

      NameType
            FROM ASN1DefinedTypesModule
            {ccitt recommendation m gnm (3100)
            informationModel (0)
            asn1Modules (2)
            asn1DefinedTypesModule (0)};

      — EXPORTS everything
      Address                 ::= GraphicString  (SIZE (64))

      AddressSequence         ::= SEQUENCE of Address

      ForwardMetric           ::= SEQUENCE of CHOICE
                              {
                              none      NULL,
                              metric INTEGER
                              }
```

```
IpForwarding          ::= BOOLEAN — TRUE reflects forwarding


IpForwardAge          ::= SEQUENCE OF LPerCounterRange

IpForwardIfIndex      ::= SEQUENCE OF ObjectInstance

IpForwardInfo         ::=  SEQUENCE OF OBJECT IDENTIFIER

IpForwardNextHop      ::= SEQUENCE OF INTEGER

IpForwardPolicy       ::=  SEQUENCE OF INTEGER

IpForwardProto        ::= SEQUENCE OF INTEGER
      {
      other           (0), — none of the following
      local           (1), — non-protocol information e.g
                           — manually configured entries
      netmgnt         (2), — set via network management protocol
      icmp            (3), — obtained via ICMP e.g. redirect
      egp             (4),
      ggp             (5),
      hello           (6),
      rip             (7),
      isol0589is-is   (8),
      iso10747is-is   (9),
      iso9542es-is    (10),
      ciscoIgrp       (11),
      bbnSpfIgp       (12),
      ospf            (13),
      bgp             (14),

      } 0..225
IpForwardType         ::= SEQUENCE OF INTEGER
      }
      other           (0), — none of the following
      invalid         (1), — an invalidated route
```

```
        direct          (2), — route to directly connected subnetwork
        indirect        (3), — route to a non-local
                             — host/network/subnet

        } 0..255

        LanPortIndex        ::= Integer16

        LanPortLastChange ::= INTEGER..— 32 bit

        LanPortLink         ::= SEQUENCE
        {
        noOfEntries  INTEGER,
        connections  SEQUENCE OF CHOICE
        }
        busConnection       [o] NULL,
        name                [1] Name — NULL reflecting
                                     — 'not connected'
        } 0..1023
}
LanPortSpecific             ::= OBJECT IDENTIFIER

LanPortSpeed                ::= CircuitBandwidth

LanPortType                 ::= INTEGER
     {
     other                  (0), — none of the following
     regular1822            (1),
     hdh1822                (2),
     ddn-x25                (3),
     rfc877-x25             (4),
     ethernet - csmacd      (5),
     iso88023 - csmacd      (6),
     iso88024 - tokenBus    (7),
     iso88025 - tokenRing   (8),
     iSO88026 - man         (9),
     starLan                (10),
```

```
        proteon - 10Mbit        (11),
        proteon - 80Mbit        (12),
        hyperchannel            (13),
        fddi                    (14),
        lapb                    (15),
        sdlc                    (16),
        dsl                     (17),  — T-1
        el                      (18),  — european equiv. of T-1
        basicISDn               (19),
        primaryISDN             (20),  — proprietary serial
        propPointToPointSerial  (21),
        ppp                     (22),
        softwareLoopback        (23),
        eon                     (24),  — CLNP over IP
        ethernet-3Mbit          (25),
        nsip                    (26),  — XNS over IP
        slip                    (27),  — generic SLIP
        ultra                   (28),  -- ULTRA technologies
        ds3                     (31) } 0..255

LPerCounterRange                ::= Count {0..42494967295} ..—— 32 bit

PortInfoID                      ::= NameType

RouteTableID                    ::= NameType

SummaryInfoID                   ::= NameType

END
```

Naming

The following name bindings shall be used as defined in the NM Forum Library.

- addValueEventRecord-nb-1

- agentConformantManagementEntity-nb-1
- alarmRecord-nb-1
- attributeChangeEventRecord-nb-1
- computerSystem-nb-2
- deenrolEventRecord-nb-1
- enrolEventRecord-nb-1
- equipment-nb-2
- equipment-nb-3
- eventLog-nb-1
- eventReportingsSieve-nb-1
- location-nb-1
- location-nb-2
- network-nb-1
- network-nb-2
- removeValueEventRecord-nb-1

The following name binding specifications have been defined for the extended specifications.

```
portInfo-lanPort NAME BINDING
      SUBORDINATE OBJECT CLASS portInfo AND SUBCLASSES;
      NAMED BY
      SUPERIOR OBJECT CLASS lanPort;
      WITH ATTRIBUTE portInfoID;
      CREATE WITH-REFERENCE-OBJECT;
      DELETE ONLY-IF-NO-CONTAINED-OBJECTS;

      REGISTERED AS {?} ;

routeTable-equipment NAME BINDING
      SUBORDINATE OBJECT CLASS routeTable AND SUBCLASSES;
      NAMED BY
      SUPERIOR OBJECT CLASS
            "NM Forum Library Vol 1 Supplement": equipment;
      WITH ATTRIBUTE routeTableID;
      CREATE WITH-REFERENCE-OBJECT;
      DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
```

```
    REGISTERED AS {?} ;

routeTable-computerSystem NAME BINDING

    SUBORDINATE OBJECT CLASS routcTable AND SUBCLASSES;
    NAMED BY
    SUPERIOR OBJECT CLASS
        "NM Forum Library Vol 1 Supplement" : computerSystem;
    WITH ATTRIBUTE routeTableID;
    CREATE WITH-REFERENCE-OBJECT;
    DELETE ONLY-IF-NO-CONTAINED-OBJECTS;

    REGISTERED AS {?};

route Table-equipment NAME BINDING
    SUBORDINATE OBJECT CLASS routeTable AND SUBCLASSES;
    NAMED BY
    SUPERIOR OBJECT CLASS
        "NM Forum Library Vol 1 Supplement": equipment;
    WITH ATTRIBUTE routeTableID;
    CREATE WITH-REFERENCE-OBJECT;
    DELETE ONLY-IF-NO-CONTAINED-OBJECTS;

    REGISTERED AS {?};

route Table-computerSystem NAME BINDING
    SUBORDINATE OBJECT CLASS routeTable AND SUBCLASSES;
    NAMED BY
    SUPERIOR OBJECT CLASS
        "NM Forum Library Vol 1 Supplement": computerSystem;
    WITH ATTRIBUTE routeTableID;

    CREATE WITH-REFERENCE-OBJECT;
    DELETE ONLY-IF-NO-CONTAINED-OBJECTS
    REGISTERED AS {?};
```

As is shown in figure 8, the LAN element manager 16 stores the LAN model on an internal management information base (MIB) 81 and this model is updated with information received from SNMP agents 82 associated with equipment on the LAN. The information is received by an SNMP manager 83 of the element manager 16 and converted into a form suitable for storage in the internal MIB 81 by conversion means 84.

The element manager 16 includes a CMIP agent 85 which can communicate in CMIP with a CMIP manager 86 of the network manager 20. The CMIP agent 85 can interact with the internal MIB 81 via conversion means 87 which converts the CMIP into the internally used protocol.

The LAN element manager 16 is characterised by the network manager 20 as a model mapper and there is an indirect relationship between the CMIP operations between the LAN element manager 16 and the network manager 20, and the SNMP operations between the LAN element manager 16 and the SNMP operations on its associated LAN. The operations on the LAN may result in changes to the internal MIB 81 which may result in CMIP events been generated. A CMIP M-GET request issued from the CMIP manager 86 will be serviced by the CMIP agent 85 by referring to the objects defined in the LAN object model stored in the internal MIB 81 via the conversion means.

If the SNMP manager 83 receives knowledge of a new device on the LAN, the MIB 81 will be updated leading to the generation of CMIP Enrol M-EVENT-REPORTS which are sent to the network manager 20. In this way the network manager 20 is made aware of new devices on the LAN (or reactivation of the previous devices) and an auto-discovery feature of the element manager 16 can be utilised by the network manager 20.

In the other direction, a Scoped M-GET request from the network manager 20 would be translated into a whole series of SNMP GetRequests and GetNextRequests as the element manager 16 attempts to obtain the latest SNMP MIB values from all the devices it manages on its LAN.

CMIP events will relate to the LAN or software applications running on the LAN.

The status of LAN devices will be conveyed to the network manager 20 the status being whether the devices are "up", "down" or "going down". The devices also indicate port link loss or loss of service from peer LANs or LAN devices.

The LAN device administrative and operational states are given by two attributes in the MIB 81. These are operationalState and administrativeState. Attribute Change Notifications will provide indication of changes in any of the states of the instances.

In order to indicate a port link loss the lanPort managed object class is used. This is derived from the equipment managed object class and provides the ability to send an alarm against the particular part on the LAN device that it represents. The loss will be indicated by the transmissionAlarm event type.

Software applications running on devices on the LAN will generate M-EVENT-REPORTS. For example, when an application is started for the first time in a real computing resource, the LAN element manager 16 will detect this and create a new userLabels entry in the corresponding managed object instance, computerSystem. The CMIP agent 85 will then send an addValue M-EVENT-REPORT to the network Manager 20. When an application is removed from the computing resource this will be indicated by the deletion of the corresponding userLabels entry in the MIB 81 and the sending of a removeValue M-EVENT-REPORT to the network manager 20 by the CMIP agent 85.

If an application listed in the userLabels should fail and this is detected by the LAN element Manager 16, then it will send an M-EVENT-REPORT to the network manager 20 with the following attributes assigned:

eventType:	processingAlarm
problemType:	sfwrEnvironmentalProblem
severity:	major
problemText:	"application <applicationName> has failed" (where applicationName is the application name)

Subsequently, if the application becomes functional again and this is detected by the LAN element manager 16, then it will send an M-EVENT-REPORT to the network manager 20 with the following attributes assigned:

eventType:	processingAlarm
problemType:	sfwrEnvironmentalProblem
severity:	clear
problemText:	"application <applicationName> has restarted"

The LAN element manager 16 may issue a SNMP GetRequest to the SNMP Agent 82. If for some reason the SNMP Agent 82 does not respond to the request an M-EVENT-REPORT is sent to the network manager 20 with the following attribute values set:

eventType:	equipmentAlarm
problemType:	noResponse
severity:	critical
problemText:	"no response to poll"

This equipmentAlarm will be sent against the equipment manager object instance representing the LAN device that is not responding to the network manager 20. The operationsState attribute will be set to disabled on the MIB 81 and an attributeChange notification will be sent to the network manager 20 by CMIP agent 85.

If during a later polling attempt by the LAN element manager 16, the device responds then a further M-EVENT-REPORT will be sent by the element manager 16 to the network manager 20 with the following attribute values set:

eventType:	equipmentAlarm
problemType:	noResponse
severity:	clear
problemText:	"device responded to poll"

The various SNMP Traps generated on the LAN will generate event reports. The SNMP Traps include:

coldStart	which indicates that the SNMP agent is reinitialising itself such that the agent's configuration or protocol implementation may be altered;
warmStart	which indicates that the SNMP agent is reinitialising itself but neither the agent's configuration or protocol implementation will be altered;
linkDown	which indicates that the sending SNMP agent recognises a failure in one of its communication links;

linkUp	which indicates that the sending SNMP agent recognises that one of its communications links has come up;
authentication-Failure	which indicates that the SNMP agent has received an SNMP message that was not properly authenticated. This is a security device and is sent when an unauthorised attempt to access or change the LAN device is made. It can be triggered by the use of an incorrect password or community string/name. The emission of this Trap can be switched "on" or "off" for some LAN devices;
egpNeighbor-Loss	which indicates that an Exterior Gateway Protocol neighbour is not reachable and the relationship no longer exists;
enterprise - Specific	which indicates that the SNMP agent recognises an enterprise specific event has occurred. The particular event will be identified within the message. This allows the use of non-standard proprietary Traps, that are defined in the MIB extensions for a particular LAN device. The enterpriseSpecific Trap contains a number that identifies the nature of the particular event that has occurred.

The information from these Traps will be mapped to the network manager 20 by the element manager 16 in a manner which will now be described.

Let us suppose that a coldStart Trap is received from the SNMP agent 82 by the network manager 20 indicating that either there is a new device or that a device that is known has been reinitialised.

If it is a new device, then it will not be known to the element manager 16 and not be modelled on the MIB 81. A new instance will be created on the MIB 81 to represent the device and an enrol M-EVENT-REPORT sent from the CMIP agent 85 to the CMIP manager 86 of the network manager 20 to make it aware of the new device.

If the device is known and there is an alarm or alarms against the managed object instance that represents it, then it can be assumed that the alarms should be cleared. An M-EVENT-REPORT is then sent to the network manager as before but with attributes:

eventType:	equipmentAlarm
problemType:	*this will be the same as the alarm or alarms raised to indicate the original fault condition(s) which this alarm now clears*
severity:	clear
problemText:	"SNMP coldStart Trap reported"

If a coldStart Trap is received from a known LAN device and there is no outstanding alarm or alarms already against the managed object instance that represents it, then an M-EVENT-REPORT is sent to the network manager 20 with the following attributes assigned:

eventType:	equipmentAlarm
problemType:	unspecified
severity:	Warning
problemText:	"SNMP coldStart Trap reported"

If the LAN device has been reinitialised following a fault then the operationalState attribute of the corresponding LAN Model managed object instance may have previously seen set to disabled. Therefore is the coldStart means the device has re-initialised, it is also assumed that the operationalState attribute value can be changed to enabled in the Internal MIB 81. An attribute change notification to indicate the change will then be sent to the network manager 20.

The warmStart Trap will be treated in exactly the same manner as the coldStart Trap.

If a linkDown Trap is sent by the LAN SNMP Agent 82 to the element manager 16, the manager 16 will determine which lanPort Managed object instance corresponds to the Trap. A CMIP M-EVENT-REPORT will be sent against the relevant lanPort instance to the CMIP manager 86 of the network manager 20, with the following attributes assigned:

eventType:	transmissionAlarm
problemType:	linkDown
severity:	critical
problemText:	"SNMP linkDown Trap reported"

The linkDown Trap causes the operationalState attribute of the corresponding lanPort managed object instance to go to disabled value. an attribute change notification will then be sent to the network manager 20.

If a linkUp Trap is sent by an SNMP Agent 82 to the element manager 16, the element manager 16 will determine which lanPort Managed object instance corresponds to the Trap. A CMIP M-EVENT-REPORT will be sent against the relevant lanPort instance with the following attributes assigned:

eventType:	transmissionAlarm
problemType:	linkUp
severity:	clear
problemText:	"SNMP linkUp Trap reported"

If a linkDown Trap had previously been sent against the lanPort, managed object instance then the linkUp Trap serves as a clear for the alarm condition caused by the linkDown Trap. The operationalState attribute value changes to enabled and an attribute change notification will be sent against the lanPort managed object instance.

If a linkUp Trap is received and there is no existing or outstanding linkDown Trap to which it corresponds then a CMIP M-EVENT-REPORT will be sent against the relevant lanPort instance with the following attributes assigned:

eventType:	transmissionAlarm
problemType:	unspecified
severity:	Warning
problemText:	"linkUp Trap reported with no outstanding SNMP linkDown Trap"

Some common makes of LAN equipment for example, Cisco routers, when they are switched on or rebooted, will send only the coldStart Trap followed by linkUp Traps for each port. Thus, it is possible for the linkUp Trap to be received when the equipment is first installed or when the equipment has reinitialised and no previous linkDown Trap has been received.

If an authenticationFailure Trap is sent by the SNMP Agent 82 to the element manager 16, the manager will determine which equipment or computerSystem managed object instance corresponds to the Trap. A CMIP M-EVENT-REPORT will be sent against the relevant instance to the CMIP manager 86 with the following attribute values assigned:

eventType:	environmentalAlarm [sensor alarm]

problemType:	instrusionDetection
severity:	Warning
problemText:	"SNMP authentication failure Trap reported from <authAddr>"

The part of the problemText attribute marked <authAddr> should be used to identify the apparent address which was the source of the attempted intrusion.

If an egpNeighborLoss Trap is sent by the SNMP Agent 82 to the element manager 16, the manager will determine which equipment or computerSystem managed object instance corresponds to the Trap originator. The element manager 16 will also determine from the variable bindings the address of the neighbouring device from which association has been lost. A CMIP M-EVENT-REPORT will be sent against the relevant instance to the CMIP manager 86 with the following attribute values assigned:

eventType:	equipmentAlarm
problemType:	externalIFDeviceProblem
severity:	critical
problemText:	"SNMP EGP neighbour loss Trap reported from <egpNeighAddr>"

The part of the problemText attribute marked <egpNeighAddr> should be used to identify the address of the other router from which association has been lost.

If an enterpriseSpecific Trap is sent by the SNMP Agent 82 to the element manager 16 it will determine which equipment or computerSystem managed object instance corresponds to the Trap originator. The element manager 16 may also determine from the variable bindings the precise meaning associated with the Trap.

A CMIP M-EVENT-REPORT will be sent to the CMIP manager 86 against the relevant instance with the following attribute values assigned:

eventType:	equipmentAlarm
problemType:	unspecified
severity:	indeterminate
problemText:	"SNMP enterprise specific Trap <Generic-Trap><Specific-Trap> reported"

It will now be readily appreciated that the element manager 16 acts in the manner of a protocol mapper. The network manager 20 holds in a data store (not shown) inventory details if the equipment modelled on the network providing the user with a knowledge of

the physical aspects of the network. For example, the attribute values of the equipment and computerSystem managed object classes may be sourced using information available form the SNMP MIB-II groups. For example, the attribute productLabel is derived from the SNMP MIB-II object sysObjectID and the typeText attribute of the equipment managed object class is derived from the SNMP object sysDescr.

Network performance will be of interest to the user of the network manager 20 and the relevant information will be passed to it by the element manager 16. This will enable the detection of congestion and potential problems on the network.

Network performance parameters include the octets in and out of particular ports, the number of unknown protocol packets received on a part, errored packets in and out of a port and incoming and outgoing packets discarded at a port.

The portInfo managed object class has an attribute inOctets which is derived from the SNMP object ifInOctets. The outErrorPackets attribute is derived from ifOutErrors.

Other performance parameters may relate to the Internet Protocol IP. For example, the total input IP packets because of an invalid address in their Reader or the total input IP packets discarded though not in error. These parameters are modelled as counter attributes in the relevant managed object class, ipSummaryInfo with attribute ipInDelivers being derived from the ipInDelivers SNMP object and ipOutRequests being derived from the ipOutRequests SNMP object.

CLAIMS

1. An internetwork system comprising a plurality of interlinked computer networks, each network having an associated manager arranged to communicate with an element on its respective network via a first network management protocol, and at least some managers including means for converting from the first network management protocol to a second protocol and further including means for communicating via the second protocol with a network manager, the network manager including control and information means arranged to allow a user of the system to control an element by issuing a command at the network manager and/or to view information on the status, configuration and/or performance of the element.

2. An internetwork system as claimed in Claim 1 in which the network manager includes a database, arranged to store a model of the internetwork, the model being arranged according to the second protocol.

3. An internetwork system as claimed in Claim 1 on Claim 2 in which the first network management protocol is a Simple Network Management Protocol (SNMP).

4. An internetwork system as claimed in Claim 1, Claim 2 or Claim 3 in which the second protocol is a Common Management Information Protocol (CMIP).

5. An internetwork system as claimed in Claim 1 including alarm means for raising an alarm against a particular element and polling information related to the said alarm to the network manager.

6. An internetwork system as claimed in Claim 5 in which the alarm means comprise port alarm means for raising an alarm against an individual port of a particular router.

7. An internetwork system as claimed in any one of the preceding claims including means for controlling a router via a command issued by the network manager.

8. An internetwork system as claimed in any one of the preceding claims including information collection means arranged to determine the performance and/or configuration of the router.

9. An internetwork system as claimed in any one of the preceding claims in which at least some of the managers include means to create objects and means to report their creation to the network manager.

10. An internetwork system as claimed in Claim 9 in which the managers report the creation of objects to the network manager by means of CMIP Enrol M-EVENT-REPORTS.

11. An internetwork system as claimed in any preceding claim in which at least some of the managers include means to convert traps received from its associated network into CMIP M-EVENT-REPORTS for transmission to the network manager.

Fig.1.

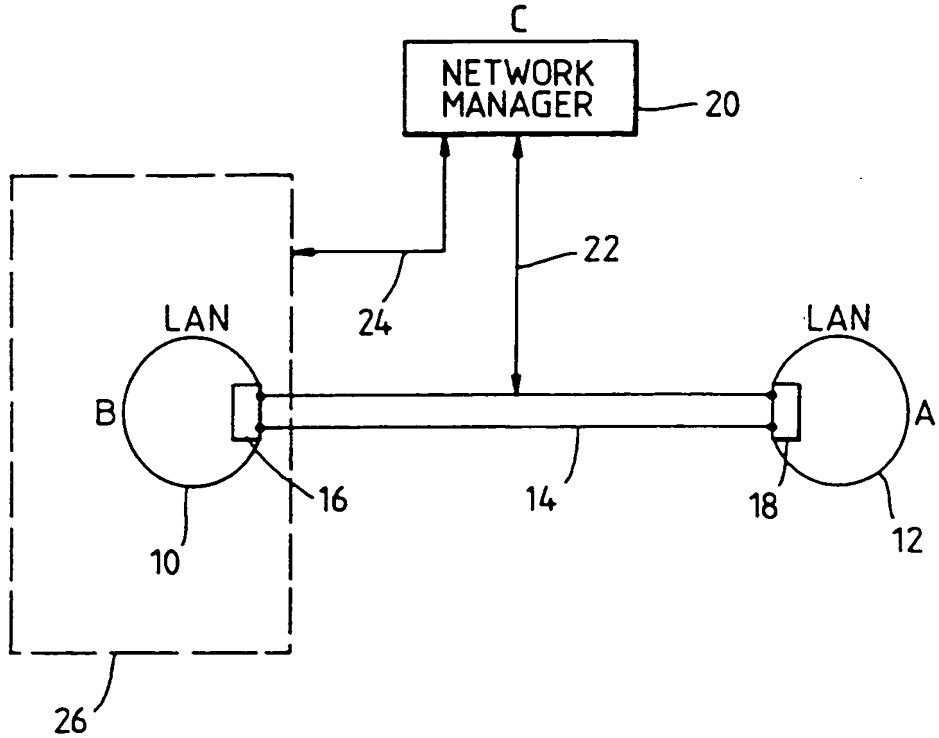

C
NETWORK MANAGER
20
22
24
LAN
LAN
B
A
16
14
18
10
12
26

Fig.2.

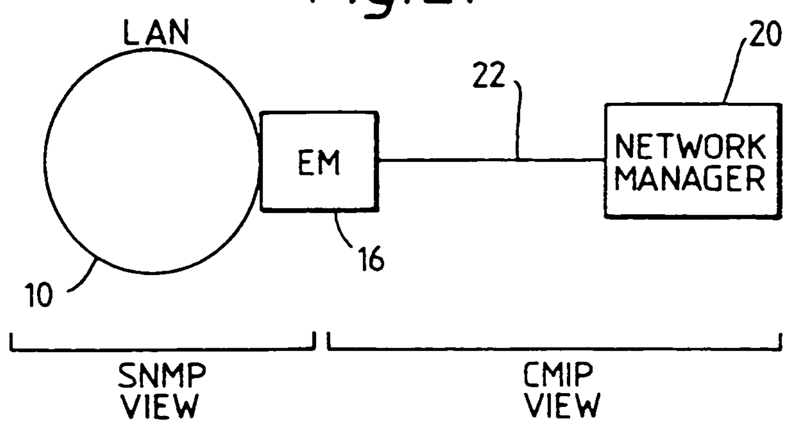

LAN
20
22
EM
NETWORK MANAGER
16
10
SNMP VIEW
CMIP VIEW

Fig. 3.

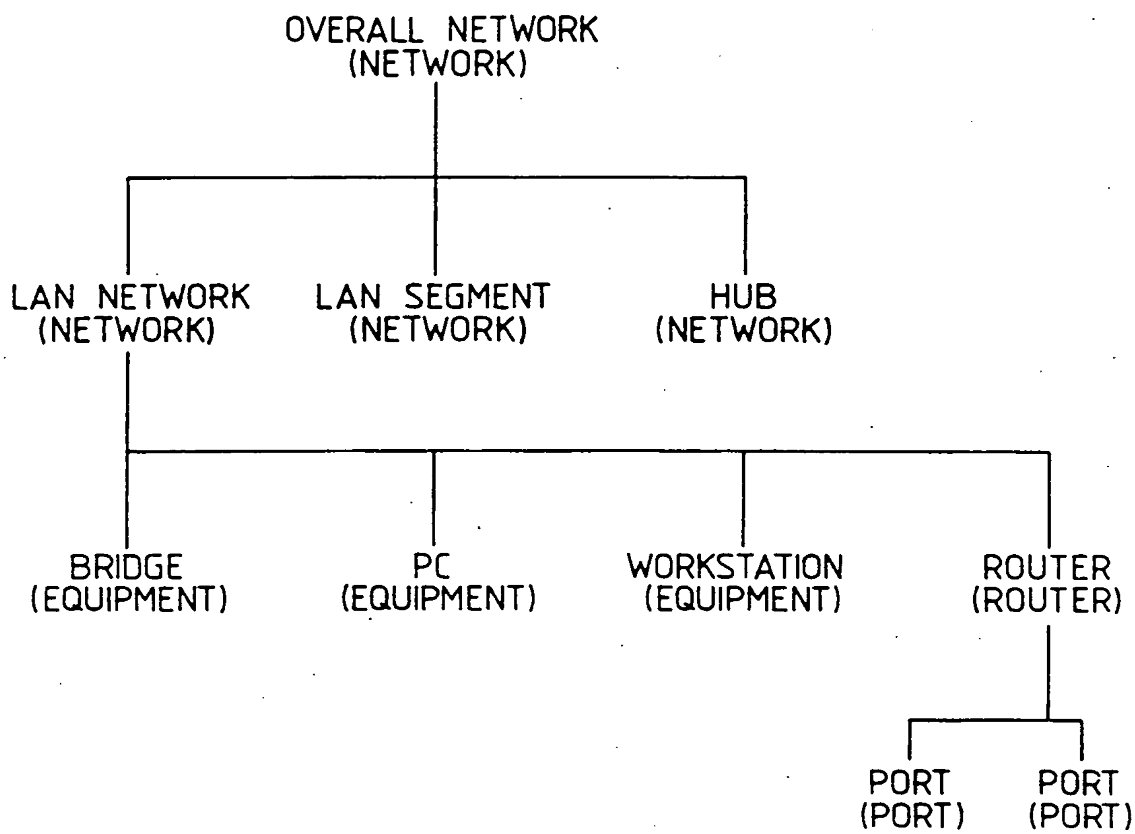

OVERALL NETWORK
(NETWORK)
LAN NETWORK
(NETWORK)
LAN SEGMENT
(NETWORK)
HUB
(NETWORK)
BRIDGE
(EQUIPMENT)
PC
(EQUIPMENT)
WORKSTATION
(EQUIPMENT)
ROUTER
(ROUTER)
PORT
(PORT)
PORT
(PORT)

Fig. 4.

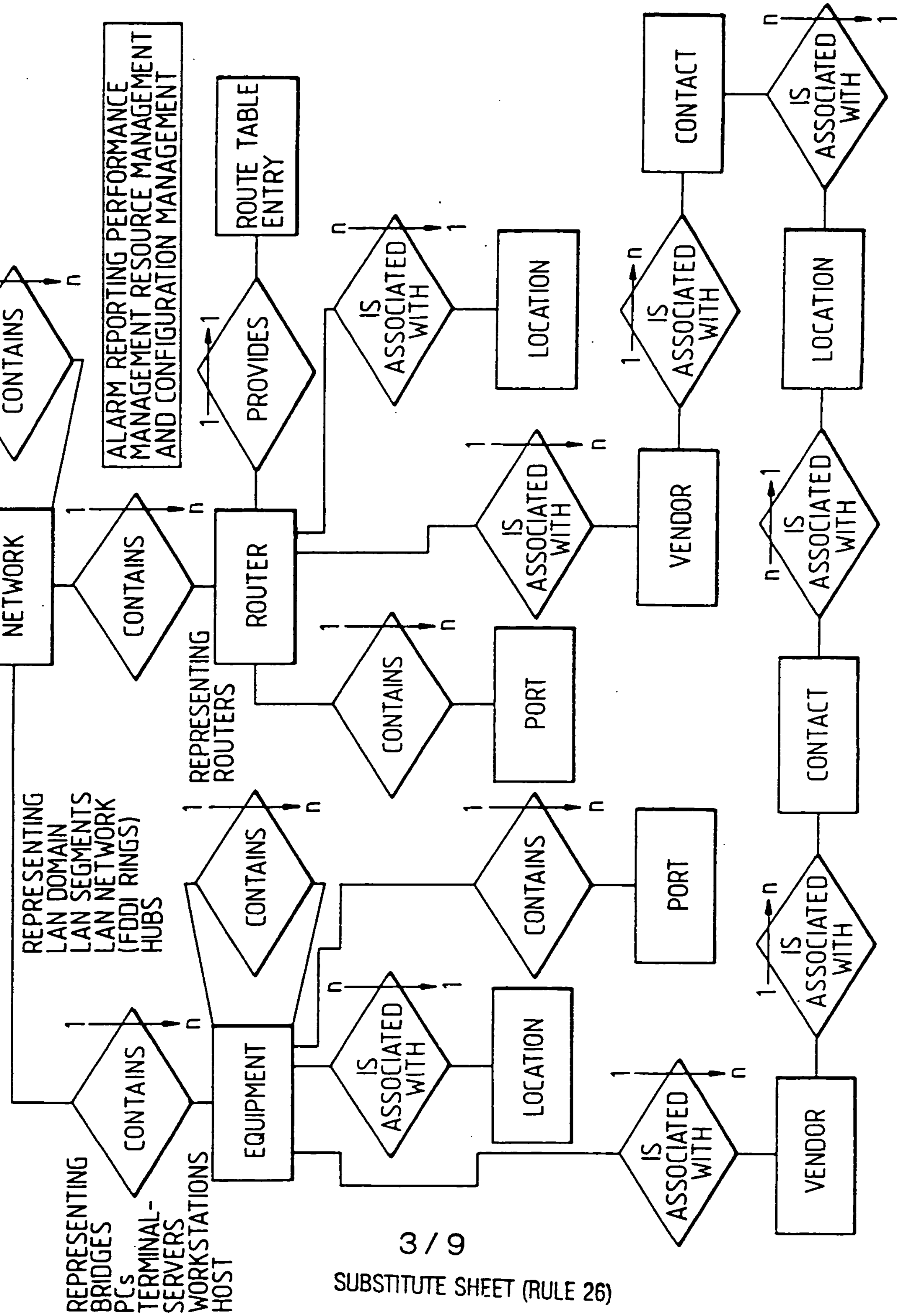

NETWORK
CONTAINS
ROUTER
EQUIPMENT
ROUTE TABLE ENTRY
PROVIDES
ALARM REPORTING PERFORMANCE MANAGEMENT RESOURCE MANAGEMENT AND CONFIGURATION MANAGEMENT
IS ASSOCIATED WITH
LOCATION
VENDOR
CONTACT
PORT
REPRESENTING ROUTERS
REPRESENTING LAN DOMAIN LAN SEGMENTS LAN NETWORK (FDDI RINGS) HUBS
REPRESENTING BRIDGES PCs TERMINAL-SERVERS WORKSTATIONS HOST
1
n

Fig.5.

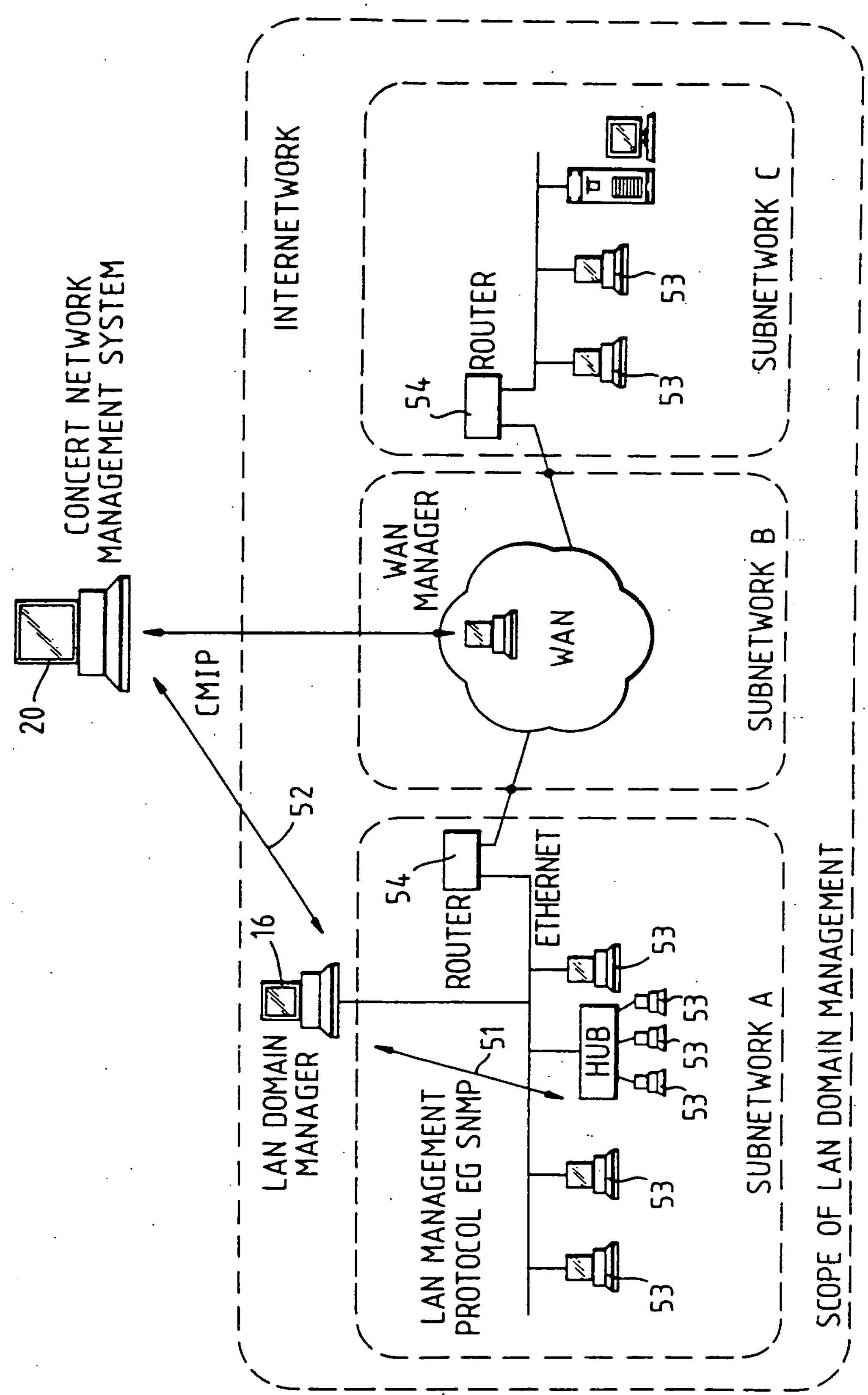
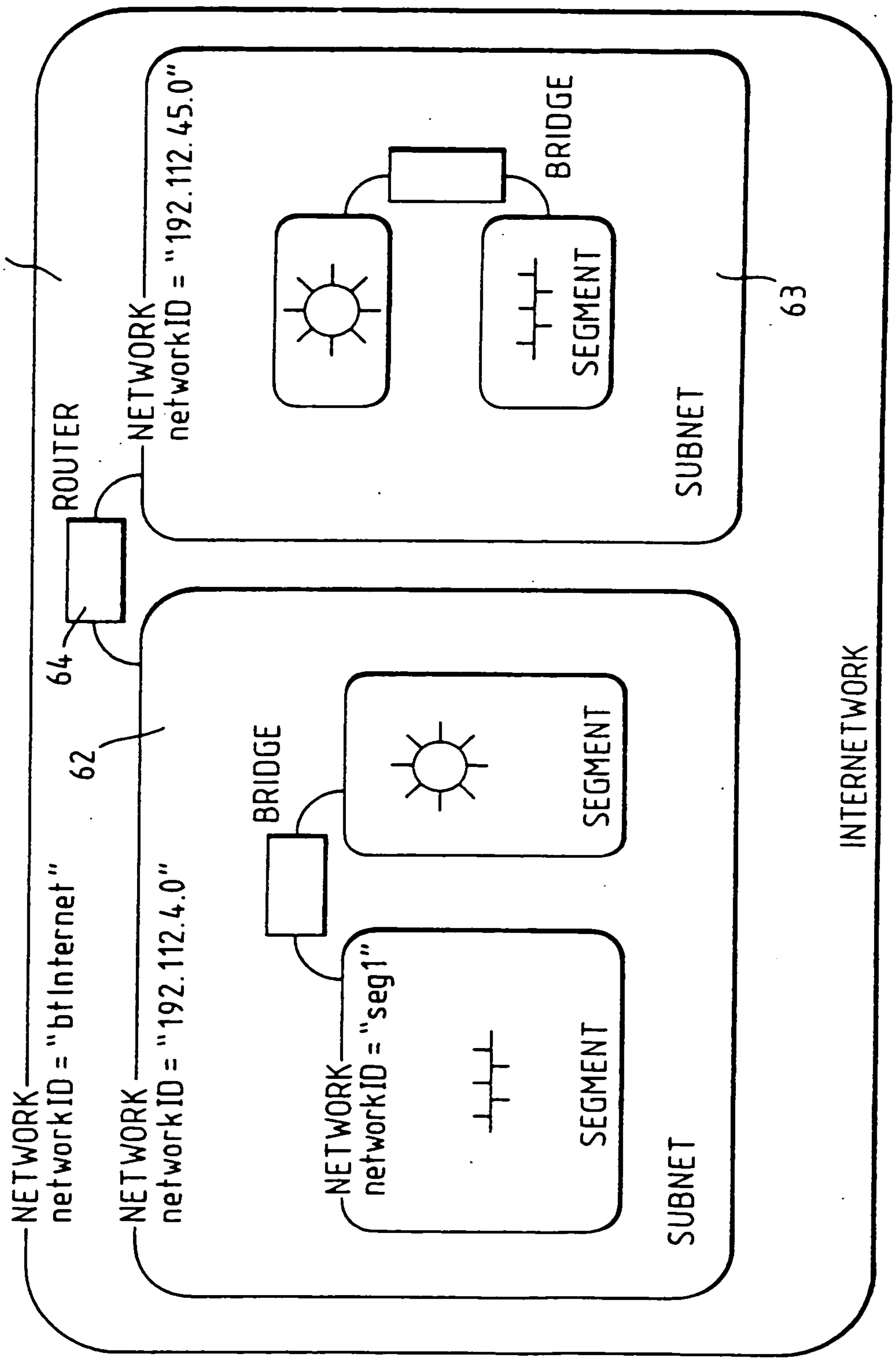

CONCERT NETWORK MANAGEMENT SYSTEM
20
CMIP
52
INTERNETWORK
LAN DOMAIN MANAGER
16
LAN MANAGEMENT PROTOCOL EG SNMP
51
54
ROUTER
ETHERNET
HUB
53
SUBNETWORK A
WAN MANAGER
WAN
SUBNETWORK B
SUBNETWORK C
SCOPE OF LAN DOMAIN MANAGEMENT

Fig. 6.


INTERNETWORK
NETWORK
networkID = "btInternet"
61
ROUTER
64
62
63
NETWORK
networkID = "192.112.45.0"
SUBNET
BRIDGE
SEGMENT
NETWORK
networkID = "192.112.4.0"
SUBNET
BRIDGE
SEGMENT
NETWORK
networkID = "seg1"
SEGMENT

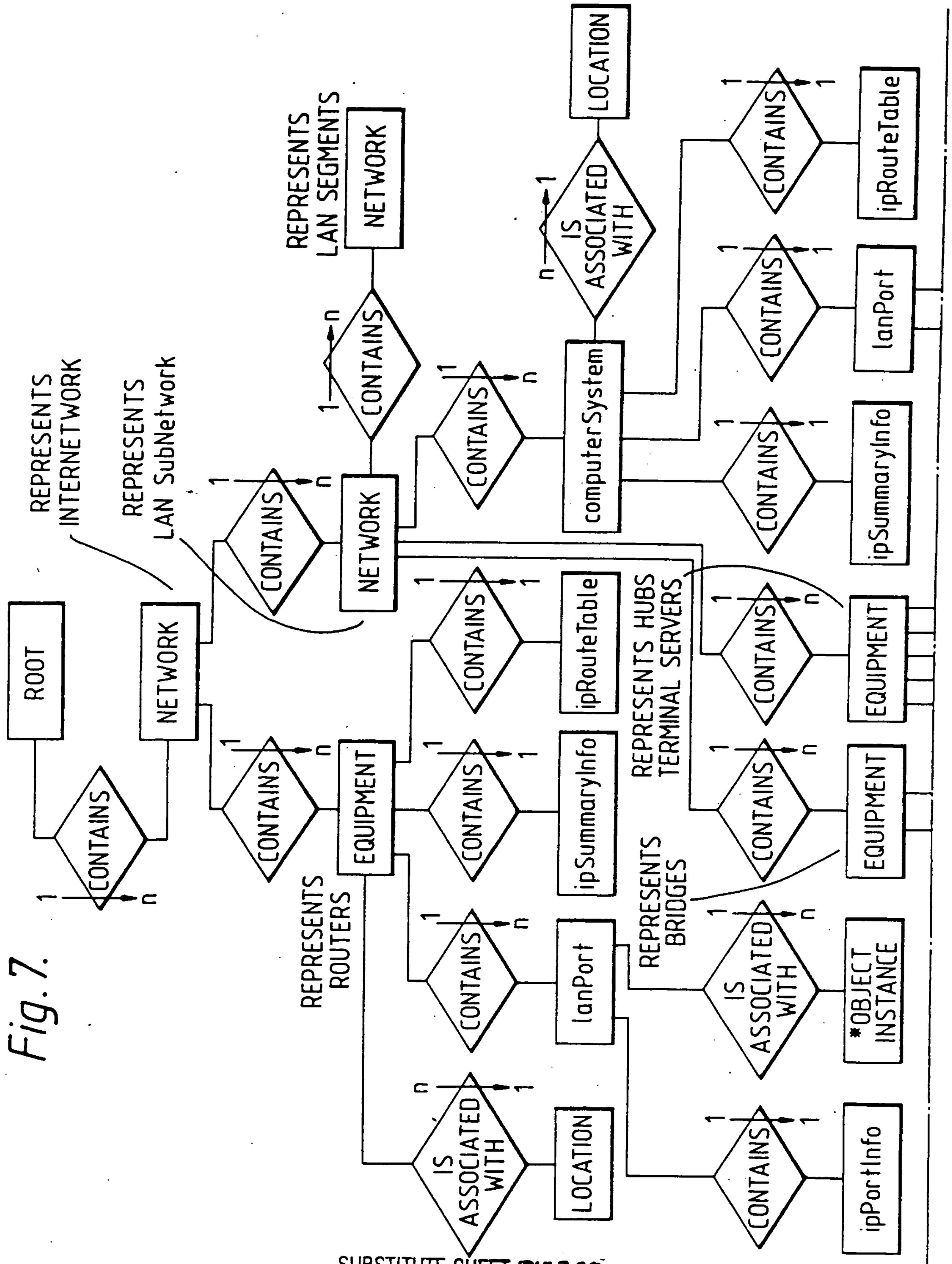

ROOT
CONTAINS
NETWORK
REPRESENTS INTERNETWORK
REPRESENTS LAN SubNetwork
CONTAINS
NETWORK
CONTAINS
NETWORK
REPRESENTS LAN SEGMENTS
CONTAINS
computerSystem
IS ASSOCIATED WITH
LOCATION
CONTAINS
ipRouteTable
CONTAINS
lanPort
CONTAINS
ipSummaryInfo
CONTAINS
EQUIPMENT
CONTAINS
ipRouteTable
CONTAINS
ipSummaryInfo
CONTAINS
lanPort
IS ASSOCIATED WITH
LOCATION
REPRESENTS ROUTERS
REPRESENTS HUBS TERMINAL SERVERS
CONTAINS
EQUIPMENT
CONTAINS
EQUIPMENT
REPRESENTS BRIDGES
IS ASSOCIATED WITH
*OBJECT INSTANCE
CONTAINS
ipPortInfo
1
n

Fig. 7.

Fig. 7(cont.)

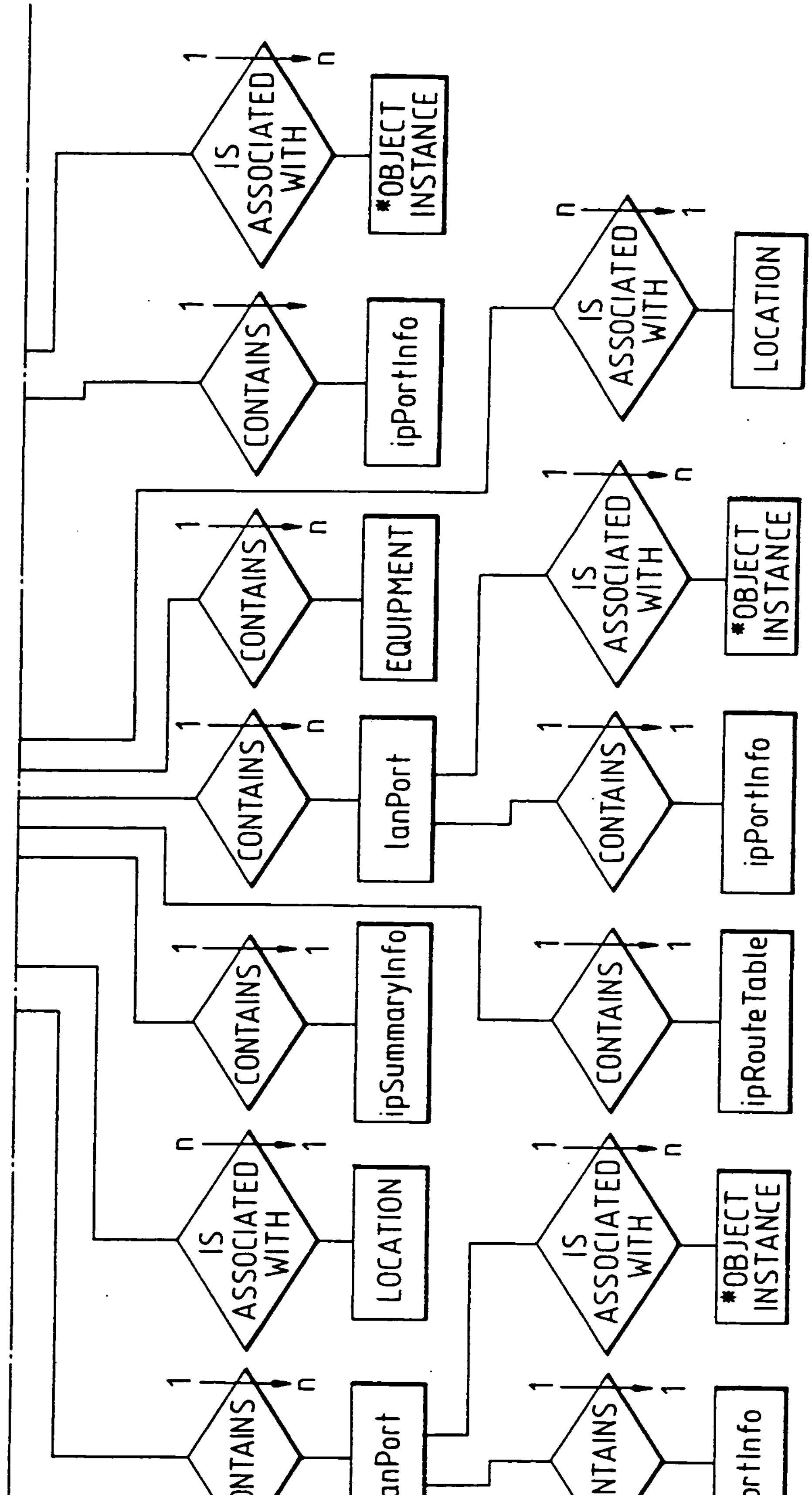

CONTAINS
lanPort
CONTAINS
PortInfo
IS ASSOCIATED WITH
*OBJECT INSTANCE
IS ASSOCIATED WITH
LOCATION
CONTAINS
ipSummaryInfo
CONTAINS
ipRouteTable
CONTAINS
lanPort
CONTAINS
ipPortInfo
IS ASSOCIATED WITH
*OBJECT INSTANCE
CONTAINS
EQUIPMENT
CONTAINS
ipPortInfo
IS ASSOCIATED WITH
LOCATION
IS ASSOCIATED WITH
*OBJECT INSTANCE
1
n

Fig.8.

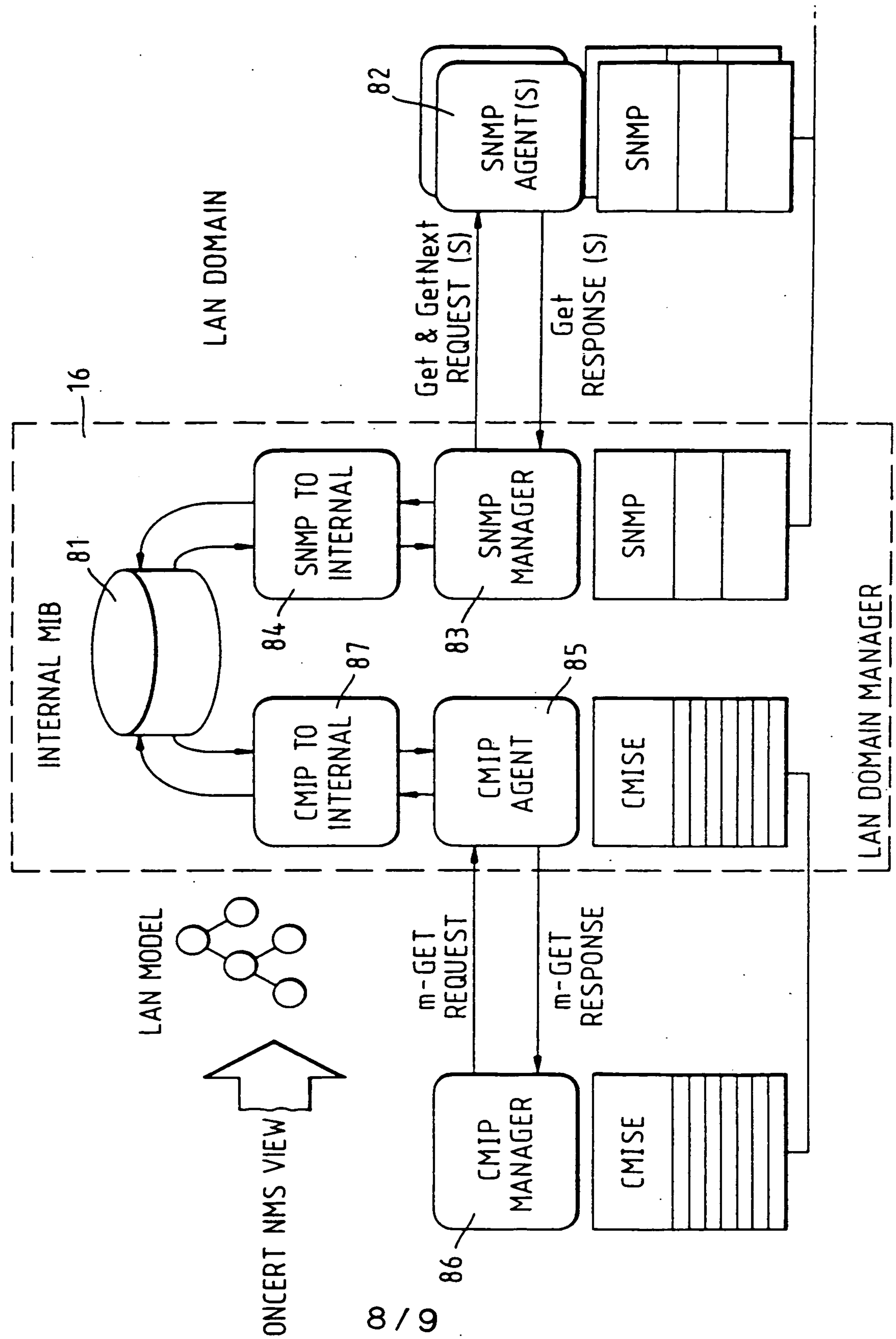
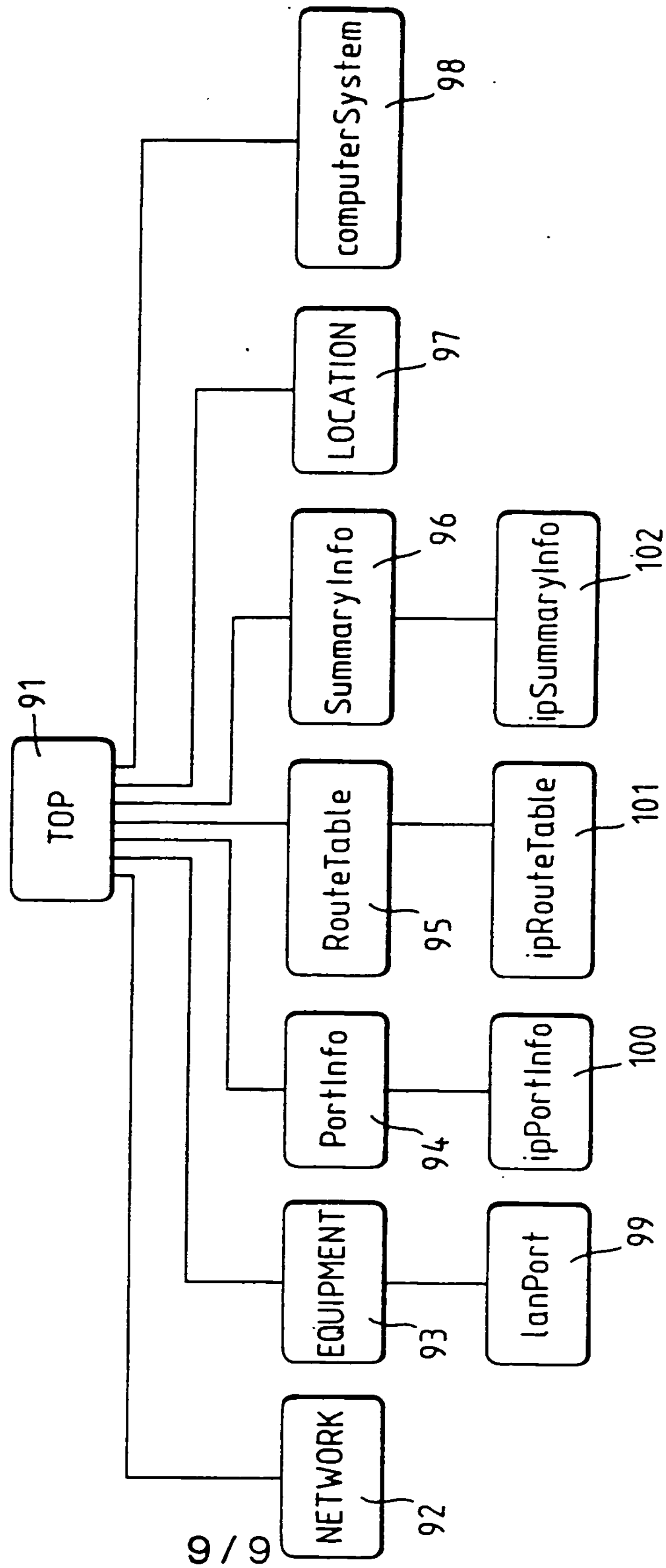

LAN DOMAIN
16
INTERNAL MIB
81
SNMP TO INTERNAL
84
CMIP TO INTERNAL
87
SNMP AGENT(S)
82
SNMP
Get & GetNext REQUEST (S)
Get RESPONSE (S)
SNMP MANAGER
83
SNMP
CMIP AGENT
85
CMISE
LAN DOMAIN MANAGER
LAN MODEL
CONCERT NMS VIEW
m-GET REQUEST
m-GET RESPONSE
CMIP MANAGER
86
CMISE

Fig.9.


TOP
91
NETWORK
92
EQUIPMENT
93
PortInfo
94
RouteTable
95
SummaryInfo
96
LOCATION
97
computerSystem
98
lanPort
99
ipPortInfo
100
ipRouteTable
101
ipSummaryInfo
102

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 94/00429

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H04L12/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	IEEE 1992 NETWORK OPERATIONS AND MANAGEMENT SYMPOSIUM, NEW YORK, US pages 556 - 565, XP344722 J.D. OLEKSIW 'LAN Internetwork Management' see the whole document	1-8
A		9-11

Y	IEEE 1992 NETWORK OPERATIONS AND MANAGEMENT SYMPOSIUM, NEW YORK, US pages 731 - 741, XP344696 I. YODA ET AL. 'configuration of a local fiber optical network management system based on multiple manager systems environment' see paragraph 3	1-8
A		9-11

	-/--	

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 June 1994	16.06.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Staessen, B

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IRE WESCON CONVENTION RECORD, vol.35, November 1991, NORTH HOLLYWOOD US pages 190 - 195 S.R.REASONER 'management by proxy agent' see page 190, right column, line 1 - page 191, left column, line 12; figures 2-4	1-8
A	IEEE NETWORK: THE MAGAZINE OF COMPUTER COMMUNICATIONS, vol.5, no.5, September 1991, NEW YORK US pages 33 - 40 T.A. COX ET AL. 'SNMP Agent Support for SMDS' see page 38, left column, line 6 - line 21	1,3,5-8
A	TECHNISCHE RUNDSCHAU, vol.83, no.24, 14 June 1991, BERN CH pages 40 - 50 F-J. KAUFFELS 'Schwaches Konzept, aber Produkte - und umgekehrt' see page 41, left column, line 10 - middle column, line 7 see page 42, middle column, line 30 - page 43, middle column, line 16	1-8
A	IEEE COMMUNICATIONS MAGAZINE, vol.29, no.7, July 1991, PISCATAWAY, NJ US pages 29 - 38 N. MODIRI 'An implementation of the common network management information service element interfaces' see figure 1	1,3-8